CLAIMS:

1. A method of controlling a process of electrochemically machining an electrically conductive workpiece the process comprising

applying an electric current between the workpiece and an electrically conductive electrode while electrolyte is supplied between the workpiece and the electrode, the method of controlling comprising

measuring a voltage induced by the electric current and

adapting at least one process control parameter in response to the measured voltage, characterized by,

determining information relating to the spectral composition of the measured voltage within a predetermined measuring period during the process of electrochemically machining and

adapting the at least one process control parameter in accordance with said information.

2. A method according to claim 1, wherein said information comprises at least one amplitude representative of at least one frequency component or at least one range of frequency components of the measured voltage.

3. A method according to claim 2 wherein said information comprises the amplitude representative of at least an harmonic frequency of the waveform constituted by the measured voltage within the predetermined measuring period..

4. A method according claim 3, wherein the method comprises expanding the wave form within the predetermined measuring period in a Fourier series of trigonometric functions and wherein said amplitudes correspond to the Fourier coefficients Ck of said series.

5. A method according to claim 4, wherein the method comprises determining the sign of the Fourier coefficients Ck of a first number of harmonics of said Fourier series

and assigning a specific process condition to at least one specific combination of Fourier coefficients indicating absence or presence of a corresponding harmonic and in case of presence, the relative sign of the corresponding harmonic.

6. A method according to claim 5, wherein the method comprises assigning a first process condition of relatively low current density to the absence of a first consecutive number of Fourier coefficients Ck.

7. A method according to claim 5, wherein the method comprises assigning a second process condition of presence of gas-filled cavities in the electrolyte to the presence of second number of consecutive Fourier coefficients Ck with mutually alternating signs.

8. A method according to claim 5, wherein the method comprises assigning a third process condition of relatively high current density to the presence of a third number of consecutive Fourier coefficients Ck with mutually equal signs.

9. A method according to claim 2, wherein said information comprises amplitudes representative of a range of frequency components greater than a predetermined frequency and the adapting of the at least one process control parameter in case of a substantially change of the amplitudes within the predetermined measuring period.

10. A method according to claim 9, wherein said information comprises a running average of said amplitudes across a predetermined time interval.

11. A method according to claim 1, wherein the at least one process control parameter involves changing applying the electric current continuously to applying the electric current intermittently.

12. A method according to claim 11, wherein

during applying the electric current continuously, the electrode and the workpiece are moved relatively to each other with a substantially constant speed and

during applying the electric current intermittently, the electrode and workpiece are moved relatively to each other in an oscillatory manner or in a repeated manner superposed on a linear movement with applying the current at or near the instant of smallest

mutual distance induced by the oscillatory or repeated distance.between the workpiece and the electrode

13. A method according to claim 12, wherein a sequence of intermittently applied electric current pulses is applied when the relative distance between the workpiece and the electrode is small during the relatively oscillatory or repeated movement.

14. A method according to claim 1, wherein the applying of electric current comprises applying electric current pulses of a normal polarity intermittently in pulse like periods, the at least one process control parameter controls applying additionally one or more electric current pulses of an opposite polarity.

15. A method according to claim 1, wherein the applying of electric current comprises applying electric current pulses of a normal polarity intermittently in pulse like periods, the at least one process control parameter controls applying additionally electric current passivation pulses of the same polarity but with an voltage having an amplitude which is inadequate to dissolve the workpiece and a passivation film on the workpiece.

16. A method according to claim 1, wherein the at least one process control parameter controls the application of an electrode cleaning electric current intermittently in one or more pulse like periods with an opposite polarity causing the electrode being cleaned of deposited waste.

17. A method according to claim 16, wherein the electrode and workpiece are moved relatively to each other in a repeated movement, the applying of electric current comprising applying electric pulses intermittently when the distance between the workpiece and the electrode is relatively small, the corresponding position of electrode and workpiece being determined by first bringing the workpiece and the electrode in contact with each other and applying a measurement current in stead of a machining current to determine a contact, the at least one process control parameter controls the applying of one or more electrode cleaning pulses prior to bringing the workpiece and electrode in contact.

18. A method according to claim 1, wherein the electrode and workpiece are moved relatively to each other in a repeated movement, the application of electric current

comprising applying electric pulses intermittently in pulse like periods when the distance between the workpiece and the electrode is relatively small, the at least one process control parameter controls changing the duration of the pulse like period.

19. A method according to claim 1, wherein the duration of the pulse like period is reduced to a value smaller then a seeding time required for formation of gas bubbles in the electrolyte.

20. A method according to claim 19, wherein the pulse period is reduced to a value between 10 to 100 microseconds.

21. A method according to claim 20, wherein the corresponding pulse forefront has a value between 100 and 1000 nanoseconds.

22. A method according to claim 19, wherein sequences of intermittently applied electric current pulses are being applied, the pauses between the pulses in a sequence having a value larger than a escape time required for escaping gas bubbles that has been formed in the electrolyte.

23. A method according to claim 22, with a ratio of pause/pulse duration between 2 and 10.

24. A method according to claim 9, wherein the at least one process control parameter controls a fast interrupt of the applied electric current.

25. A method according to claim 1, wherein the electrode and workpiece are moved relatively to each other in an oscillatory movement, the electric current being supplied intermittently in pulse like periods when the distance between the workpiece and the electrode is relatively small, the at least one process control parameter comprises the relative phase shift between the oscillatory movement and the start of applying the electric current each oscillatory movement.

26. A method according to claim 1, wherein the electrode and wordpiece are moved relatively to each other in an oscillatory movement, the electric current being supplied

intermittently in pulse like periods when the distance between the workpiece and the electrode is relatively small, the at least one process control parameter comprises an electrolyte pressure.

27. A method according to claim 1, wherein the electrode and workpiece are moved relatively to each other in an oscillatory movement, the electric current being supplied intermittently in pulse like periods when the distance between the workpiece and the electrode is relatively small, the at least one process control parameter comprises the relative machining speed the workpiece and electrode are being moved relatively to each other.

28. A method according to claim 1, wherein the process of electrochemically machining comprises applying the electric current in pulse like periods, wherein the predetermined measuring period substantially corresponds to the duration of a pulse.

29. A method according to claim 1, wherein the process of electrochemically machining comprises applying the electric current substantially continuously during a first time duration, wherein the predetermined measuring period is a fraction of said first time duration, such that variations in process conditions may be measured within the measuring period.

30. A method of electrochemically machining an electrically conductive workpiece, the method comprising

applying an electric current between the workpiece and an electrically conductive electrode while electrolyte is supplied between the workpiece and the electrode,

the method comprises

a material removing step wherein the electric current is supplied continuously while the workpiece and the electrode are moved relatively to each other with a substantially constant speed and

a workpiece shaping step wherein the electric current is supplied intermittently in pulse like periods while the workpiece and the electrode are moved relatively to each other in a oscillatory or repeated movement, the electric current being supplied when the distance between the workpiece and the electrode is relatively small.

31. A method according to claim 30, wherein a sequence of intermittently applied electric current pulses is applied when the distance between the workpiece and the electrode is relatively small during the relatively oscillatory or repeated movement.

Sub A1

32. A method according to claim 31 or 30, wherein the duration of the pulse like period is reduced to a value smaller then a seeding time required for formation of gas bubbles in the electrolyte, such as for instance the formation of hydrogen gas.

33. A method according to claim 32 or 30, wherein the pulse period is reduced to a value between 10 to 100 microseconds.

34. A method according to claim 32, wherein the pauses between the pulses in a sequence have a value larger than a escape time required for escaping gas bubbles that has been formed in the electrolyte.

35. A method according to claim 34, with a ratio of pause/pulse duration between 2 and 10.

36. A method according to claim 30, wherein the workpiece shaping step comprises applying electric current pulses of a normal polarity intermittently in pulse like periods and applying additionally electric current passivation pulses of the same polarity but with a voltage having an amplitude which is inadequate to dissolve the workpiece and a passivation film on the workpiece.

37. A method according to claim 30, wherein the method comprises a workpiece finishing step comprising applying electric current pulses of a normal polarity intermittently in pulse like periods and applying additionally one or more electric current pulses of an opposite polarity.

38. A method according to claim 30, wherein the method comprises a electrode tool cleaning step comprising applying of electric current intermittently in one or more pulse like periods with an opposite polarity causing the electrode being cleaned of deposited waste.

39. An arrangement for electrochemically machining an electrically conductive workpiece by applying an electric current between a workpiece and an electrically conductive electrode while electrolyte is supplied between the workpiece and the electrode, the arrangement comprises:

an electrically conductive electrode (3);

means for positioning (4,5) the electrode and the workpiece (1) in a spatial relationship so as to maintain a gap between the electrode (3) and the workpiece (1);

means for supplying (7) the electrolyte into the gap;

an electric power supply source (11) , which is electrically connectable to the electrode (3) and the workpiece (1) to apply an electric current between the workpiece (1) and the electrode (3),

characterized in that, the arrangement further comprises

voltage measurement means (17,22) electrically connected with the electrode (3) and the workpiece (1) or with an impedance circuitry in a power supply line between the power supply source (11) and the workpiece (1) or the electrode (3);

process adjusting means (16,24,27,30) for adjusting at least one process control parameter of the electrochemically machining process;

controlling means (12) connected with the voltage measurement means (17,22) and the process adjusting means (16,24,27,30)

the controlling means (12) being provided with analyzing means (48) for determining information (Ck,Ac) relating to the spectral composition of a measured voltage (Um) within a predetermined period (Tm, Tm') during the process of electrochemically machining and

the controlling means (12) being adapted to adjust the at least one process control parameter signal (Pi, S1,S2, SEL1, SEL2, CI1,CU1, ..) in accordance with said spectral information.

40. Arrangement according to claim 39, characterized in that,

the analyzing means (48) are adapted to generate at least one spectral signal representative of an amplitude of at least one frequency component or at least one range of frequency components of the measured voltage.

41. Arrangement according to claim 40, characterized in that,

the analyzing means (48) comprises harmonic detecting means (53) for generating a spectral signal (Ck) representative of at least an harmonic frequency of the waveform constituted by the measured voltage (Um) within the predetermined measuring period (Tm).

42. Arrangement according to claim 41, characterized in that,

the analyzing means (48) comprises waveform expanding means (53) expanding the waveform within the predetermined measuring period (Tm, Tm') in a Fourier series and for

generating spectral signals representative of the amplitudes of Fourier coefficients Ck of the Fourier series.

43. Arrangement according to claim 42, characterized in that,

the waveform expanding means (53) comprises sign determining means to determine the sign of the spectral signals representing a first number of harmonics of said Fourier series,

the controlling means (12) comprises assigning means (54) to generate a specific process condition signal in case of a specific combination of signs of the spectral signals Ck representing the first number of harmonics are being supplied to the controlling means (49)

44. Arrangement according to claim 43, characterized in that,

the assigning means (54) are adapted to generate a first process condition signal (T) indicative of a relatively low current density in case if the spectral signals indicate the absence of a first number of Fourier coefficients Ck.

45. Arrangement according to claim 43, characterized in that,

the assigning means (54) are adapted to generate a second process condition signal (T) indicative of the presence of gas-filled cavities in the electrolyte in case if the spectral signals indicate a second number of consecutive Fourier coefficients Ck with mutually alternating signs.

46. Arrangement according to claim 43, characterized in that,

the assigning means (54) are adapted to generate a third process condition signal (T) indicative of the presence of a relatively high current density in case of a third number of consecutive Fourier coefficients Ck with mutually equal signs.

47. Arrangement according to claim 40, characterized in that,

the analyzing means (48) comprises

high pass filtering means (55) for generating spectral signals representative of a range of frequency components greater than a predetermined frequency and

spectral signal change detecting means (59) for detecting a rapid change of the generated spectral signals within the predetermined measuring interval (Tm) and supplying a corresponding spectral signal change signal (Ac) to the controlling means,

the controlling means (12) being adapted to adjust the at least one process control parameter signal in case of the spectral signal change signal (Ac) being supplied.

48. Arrangement according to claim 47, characterized in that,

the analyzing means (48) comprise averaging means (58) for averaging the amplitudes of the spectral signals generated across a predetermined time interval (Tm).

49. Arrangement according to claim 39, characterized in that,

the electric power supply source (11) comprises a constant current or a constant voltage source (15,23) for applying the electric current continuously,

a pulsed current or pulsed voltage source (26,29) for applying the electric current intermittently and

switching means (19,25,28,31) to switch between the respective sources.

50. Arrangement according to claim 49, characterized in that,

the means for positioning comprises :

first positioning means (4) for moving the electrode (3) and the workpiece (1) relatively to each other with a substantially constant speed and

second positioning means (5) for moving the electrode (3) and the workpiece (1) relatively to each other in oscillatory or repeated manner.

51. Arrangement according to claim 50, characterized in that, the pulsed current source (26,29) is adapted to generate a sequence of intermittently applied pulses when the

relative distance between the workpiece (1) and the electrode (3) is small during the relatively oscillatory or repeated movement.

52. Arrangement according to claim 39, wherein the pulsed current source (26,29) is adapted to apply electric current pulses of a normal polarity intermittently in pulse like periods, characterized in that,

the pulsed current source (26,29) is further adapted to apply additionally one or more current pulses of an opposite polarity in response to at least one process control parameter signal (SEL1,SEL2,CI1,CU1...)

53. Arrangement according to claim 39, wherein the pulsed current source (26,29) is adapted to apply electric current pulses of a normal polarity intermittently in pulse like periods, characterized in that,

the pulsed current source (26 ,29) is further adapted to apply additionally electric passivation pulses of the same polarity but with an voltage having an amplitude which is inadequate to dissolve the workpiece (1) and a passivation film on the workpiece (1) in response to at least one process control parameter signal (SEL1, SEL2, CI1,CU1...).

54. Arrangement according to claim 39, wherein the pulsed current source (26,29) is adapted to apply an electrode cleaning electric current intermittently in one or more pulse like periods with an opposite polarity causing the electrode (3) being cleaned of deposited waste in response to at least one process control parameter signal(SEL1, SEL2, CI1, CU1..).

55. Arrangement according to claim 54, wherein the positioning means (4,5) are adapted to move the electrode (3) and the workpiece (1) to each other in a repeated movement, the pulsed current source (26,29) is adapted to apply electric current pulses intermittently when the distance between the workpiece (1) and the electrode (3) is relatively small, the control unit (12) is adapted to determine the corresponding position of electrode (3) and workpiece (1) by first bringing the workpiece (1) and the electrode (3) in connection with each other and applying a measurement current in stead of a machining current to determine a connection, characterized in that, the pulsed current source (26,29) is adapted to apply one or more electrode cleaning pulses prior to bringing the workpiece (1) and electrode (3) in connection.

56. Arrangement according to claim 39, wherein the positioning means (4,5) are adapted to move the electrode (3) and the workpiece(1) relatively to each other in a repeated movement, the pulsed current source (26,29) is adapted to apply electric pulses intermittently in pulse like periods when the distance between the workpiece (1) and the electrode (3) is relatively small, characterized in that, the pulsed current source (26,29) is adapted to change the duration of the pulse like period in response to the at least one process control parameter signal.

57. Arrangement according to claim 56, wherein the pulsed current source (26,29) is adapted to apply electric pulses with a duration of the pulse like period reduced to a value smaller then a seeding time required for formation of gas bubbles in the electrolyte, such as for instance the formation of hydrogen gas.

58. Arrangement according to claim 57, wherein the pulse period is reduced to a value between 10 to 100 microseconds.

59. Arrangement according to claim 58, wherein the corresponding pulse forefront period has a value between 100 and 1000 nanoseconds.

60. Arrangement according to claim 57, wherein the pulsed current source (26,29) is adapted to generate sequences of intermittently applied electric current pulses, the pauses between the pulses in a sequence having a value larger than a escape time required for escaping gas bubbles that has been formed in the electrolyte.

61. Arrangement according to claim 60, with a ratio of pause/pulse duration between 2 and 10.

62. Arrangement according to claim 33, wherein the electric power supply source (11) is adapted to interrupt the supply of electric current fast in response to the at least one process control parameter signal.

63. Arrangement according to claim 39, wherein the positioning means (4,5) are adapted to move the electrode (3) and the workpiece(1) relatively to each other in an oscillatory movement, the pulsed current source (26,29) is adapted to apply electric pulses

intermittently in pulse like periods when the distance between the workpiece (1) and the electrode (3) is relatively small, characterized in that, the controlling means (12) are adapted to change the relative phase shift (φ) between the oscillatory movement and the start of applying the electric current each oscillatory movement in response to the at least one process control parameter signal.

64. Arrangement according to claim 39, wherein the positioning means (4,5) are adapted to move the electrode (3) and the workpiece(1) relatively to each other in an oscillatory movement, the pulsed current source (26,29) is adapted to apply electric pulses intermittently in pulse like periods when the distance between the workpiece (1) and the electrode (3) is relatively small, characterized in that, the controlling means (12) are adapted to change the electrolyte pressure (Pel) in response to the at least one process control parameter signal.

65. Arrangement according to claim 39, wherein the positioning means (4,5) are adapted to move the electrode (3) and the workpiece(1) relatively to each other in an oscillatory movement, the pulsed current source (26,29) is adapted to apply electric pulses intermittently in pulse like periods when the distance between the workpiece (1) and the electrode (3) is relatively small, characterized in that, the controlling means (12) are adapted to change the relative machining speed the workpiece (1) and the electrode (3) are moved to each other in response to the at least one process control parameter signal.

66. Arrangement according to claim 39, wherein the electric power supply source (11) is adapted to apply electric current pulses in pulse like periods, characterized in that, the predetermined measurement period (Tm, Tm') substantially corresponds to the duration of a pulse.

67. Arrangement according to claim 39, wherein the electric power source (11) is adapted to apply the electric current substantially continuously during a first time duration, characterized in that, the predetermined measurement period (Tm, Tm') is a fraction of said first time duration, such that variation in process conditions may be measured within the measuring period (Tm, Tm').

68. An arrangement for electrochemically machining an electrically conductive workpiece by applying an electric current between a workpiece and an electrically conductive electrode while electrolyte is supplied between the workpiece and the electrode, the arrangement comprises:

an electrically conductive electrode (3);

means for positioning (4,5) the electrode and the workpiece (1) in a spatial relationship so as to maintain a gap between the electrode (3) and the workpiece (1);

means for supplying (7) the electrolyte into the gap;

an electric power supply source (11) , which is electrically connectable to the electrode (3) and the workpiece (1) to apply an electric current between the workpiece (1) and the electrode (3),

controlling means (12) connected to the means for positioning (4,5) and the electric power supply source (11),

characterized in that,

the controlling means (12) are adapted to operate in a material removing operation mode or in a workpiece shaping operation mode,

the means for positioning (4,5) are adapted to move the electrode (3) and the workpiece (1) relatively to each other with a substantially constant speed in the material removing operation mode and in an oscillatory or repeated movement in the workpiece shaping operation mode,

the electric power supply source (11) is adapted to supply the current continuously in the material removing operation mode and intermittently in pulse like periods when the relative distance between the workpiece (1) and the electrode (3) is relatively small in the workpiece shaping operation mode.

69. Arrangement according to claim 68, wherein the electric power source (11) is adapted to generate a sequence of intermittently applied electric current pulses when the distance between the electrode (3) and the workpiece (1) is relatively small in the workpiece shaping operation mode.

70. Arrangement according to claim 69 or 68, wherein the pulsed current source (26,29) is adapted to apply electric pulses with a duration of the pulse like period reduced to a value smaller then a seeding time required for formation of gas bubbles in the electrolyte, such as for instance the formation of hydrogen gas

Sub A2

71. Arrangement according to claim 70, wherein the pulse period is reduced to a value between 10 to 100 microseconds.

72. Arrangement according to claim 70, wherein the pulsed current source (26,29) is adapted to generate sequences of intermittently applied electric current pulses, the pauses between the pulses in a sequence having a value larger than a escape time required for escaping gas bubbles that has been formed in the electrolyte.

73. Arrangement according to claim 72, with a ratio of pause/pulse duration between 2 and 10.

74. Arrangement according to claim 68, characterized in that,

the electric power supply source (11) is adapted in the workpiece shaping operation mode to apply electric current pulses of a normal polarity intermittently in pulse like periods and to apply additionally electric passivation pulses of the same polarity but with and voltage having an amplitude which is inadequate to dissolve the workpiece (1) and a passivation film on the workpiece (1)

75. Arrangement according to claim 68, characterized in that,

the controlling means (12) are adapted to operate in a workpiece finishing operation mode and

the electric power supply source (11) is adapted in the workpiece shaping operation mode to apply electric current pulses of a normal polarity intermittently in pulse like periods and to apply additionally one or more electric current pulses of an opposite polarity.

76. Arrangement according to claim 68, characterized in that,

the controlling means (12) are adapted to operate in an electrode tool cleaning operation mode and

the electric power supply source (11) is adapted in the electrode tool cleaning operation mode to apply electric current pulses intermittently in one or more pulse like periods with an opposite polarity causing the electrode being cleaned of deposited waste.

77. A method of electrochemically machining an electrically conductive workpiece by applying an electric current between the workpiece and an electrically conductive electrode while electrolyte is supplied between the workpiece and the electrode, the method comprising:

a material removing step wherein the electric current is supplied continuously while the workpiece and the electrode are moved relatively to each other with a substantially constant speed,

a workpiece shaping step wherein the electric current is supplied intermittently in pulse like periods while the workpiece and the electrode are moved relatively to each other in a oscillatory or repeated movement, the electric current being supplied when the distance between the workpiece and the electrode is relatively small, the method further comprising :

measuring a voltage induced by the electric current,

determining information relating to the spectral composition of the measured voltage within a predetermined measuring period during the process of electrochemically machining and

adapting at least one process control parameter in accordance with said information.